

PROTON RADIATION THERAPY

A COMPARISON OF RANDO PHANTOM LUNG DOSE FROM PROTON AND ELECTRON THERAPY OF THE CHEST WALL

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Electron arc therapy is the optimal irradiation technique used in the treatment of large superficial volumes which follow curved surfaces. It is an especially important treatment for postmastectomy breast cancer patients. However, the complex geometry of the upper thorax, axilla, and supraclavicular fossa makes this treatment a technical challenge. Consideration of the curvature of the thorax, the varying depths of the target volumes and the proximity of the underlying radiosensitive lung must be taken into account in the treatment planning process. This has led to treatments which include beam compensation, planned alteration of the dose rate over the arc, variable width secondary collimation, and segmental changes in energy over the arc to obtain an optimal target volume coverage. This complex treatment planning may reduce the volume of the lung that receives a significant dose but still the dose to the lung can be high. Further, the effect of this high dose is exacerbated when this therapy is used as an adjuvant to chemotherapeutic agents that have a side effect of sensitizing lung tissue to radiation damage. High-energy proton arc therapy is an alternative treatment modality which, due to the proton beam's rapid dose drop off beyond the spread out Bragg peak (SOBP), allows lung irradiation to be minimized. This report compares proton arc therapy to that of electron arc and quantifies the relative differences in lung dose.

200-MeV protons from the Indiana University Cyclotron were range shifted and modulated to provide a 4-cm spread-out Bragg peak with 3 cm (water equivalent) of penetration. The chest wall of the Rando phantom was irradiated by protons using a 20 cm×4 cm strip field while it rotated on a platform at approximately 1-rpm. This rotating platform was also used in a similar Rando chest wall treatment with 12-MeV electrons. The electron energy was chosen such as to irradiate the same target volume as treated with the proton arc. The relative dose distribution within the irradiated volume was measured with Kodak XV2 film, and the dose delivered (50 cGy to the target volume) was measured with extruded rod LiF-100 thermo-luminescent dosimeters (TLD). The TL level was measured using a Harshaw 2000 TLD reader, and film optical density measurements were performed using an RFA 300 Scanditronix digital densitometer. Calibration curves for both the film and TLDs were obtained in a solid-water phantom.

Films were retained in their paper cassettes and cut to the shape of 5 consecutive Rando phantom slices (15–20) with their edges sealed with black electrical tape to prevent exposure to light. Films were sandwiched between the appropriate phantom slices. The central slice (#17) was selected for normalization and treatment planning. Two TLD rods

were inserted into each of 10 chosen holes in the Rando phantom within the target volume and lung. The Rando phantom was assembled, squeezed in its vise to exclude air pockets from the film cassettes, and then placed on the rotating platform. Tertiary shaping lead shields were added to its surface. For irradiation in the proton beam, the whole phantom was slightly tilted to prevent normal incidence of protons on the phantom and so avoid channelling of protons through small air gaps between slices. For electrons this precaution was not necessary because of their higher scattering power.

All films were processed in the same session to remove processor effects. The HD curves were obtained for both proton and electron irradiation and used to convert optical density to absorbed dose. The isodose tracking feature of the RFA 300 digital densitometer was used to read the exposed films, and the accuracy of this RFA 300 digital densitometer was verified by remeasuring some points with a high-resolution optical densitometer.

The irradiation setup for both techniques used a horizontal beam, with Rando on a platform which rotated about the vertical axis. We chose not to use a bolus in either technique, despite the obvious benefits for tumor volume coverage, since the project aim was to investigate the reduction in dose to lung resulting from using proton beams versus electron beams, not to produce an optimized treatment plan. The isodose distributions resulting from irradiating the Rando phantom with (a) electron and (b) proton arcs are shown for slice #17 in Fig. 1 and Fig. 2, respectively. The difference in integral lung

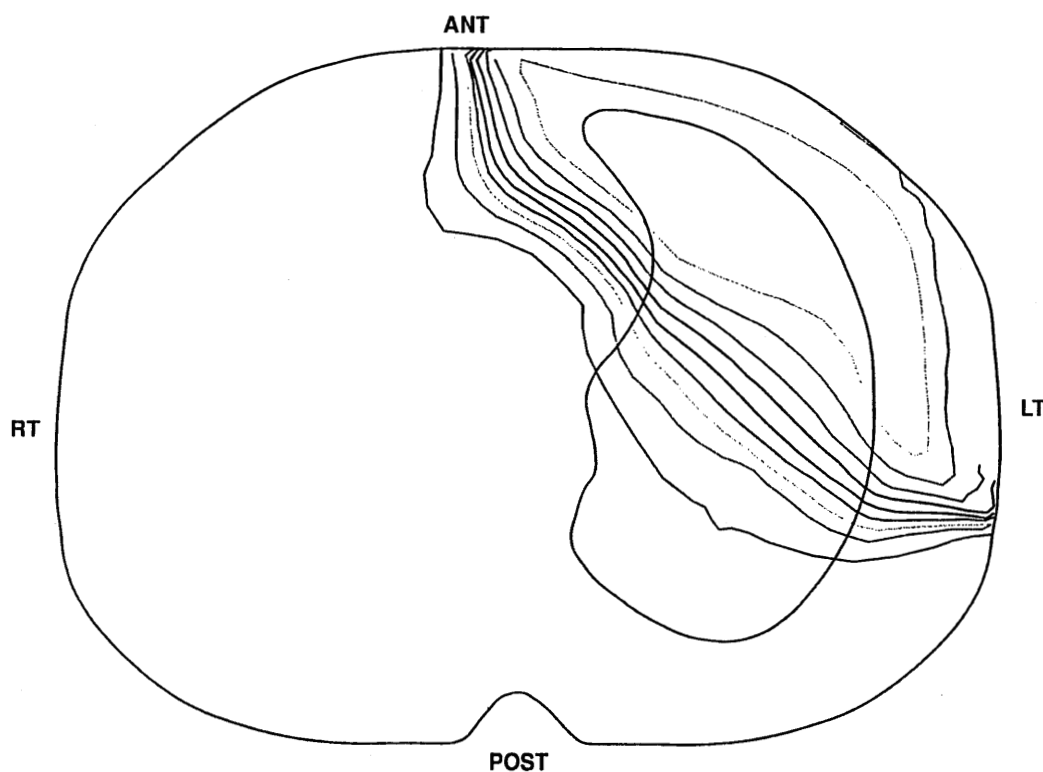


Figure 1. The isodose distribution from the 12-MeV electron arc therapy.

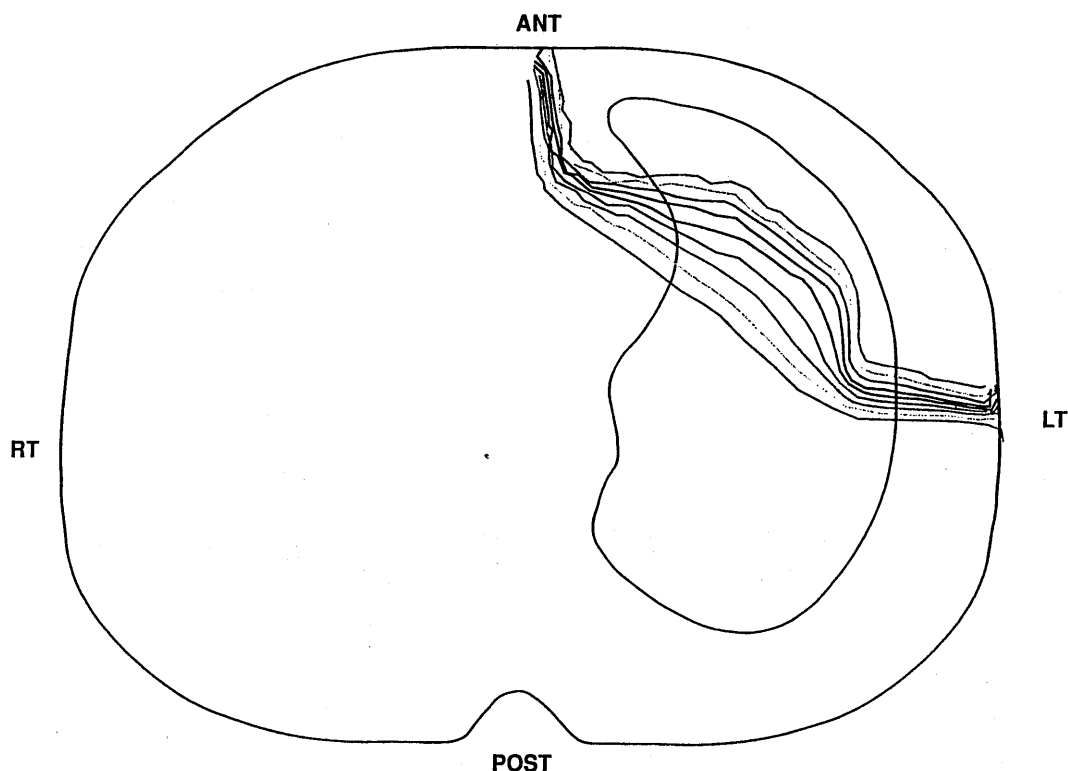


Figure 2. The isodose distribution from the proton arc therapy.

dose between proton and electron irradiation is quite dramatic. The proton-beam isodose curves follow the curvature of the surface, and with the appropriate bolus the irradiation of the lung could be totally avoided. In the case of the electron arc, the beam is penetrating much further into the lung and if a bolus was used the amount of lung irradiated to high dose levels would remain substantial. Figure 3 presents the lung-dose volume histogram for slice 17/18 of the Rando. Figure 4 shows the total lung-dose histograms and demonstrates that the integral dose to the lung is reduced with proton irradiation by a factor of 2.3.

This study demonstrates the superiority of proton arc therapy of the chest wall compared to that of electron arc when lung dose must be minimized. Optimization of the therapy to achieve the "best" results for either modality of irradiation was not attempted and in this case the integral dose to the lung was reduced by a factor of 2.3 using protons compared to the integral dose from electrons.

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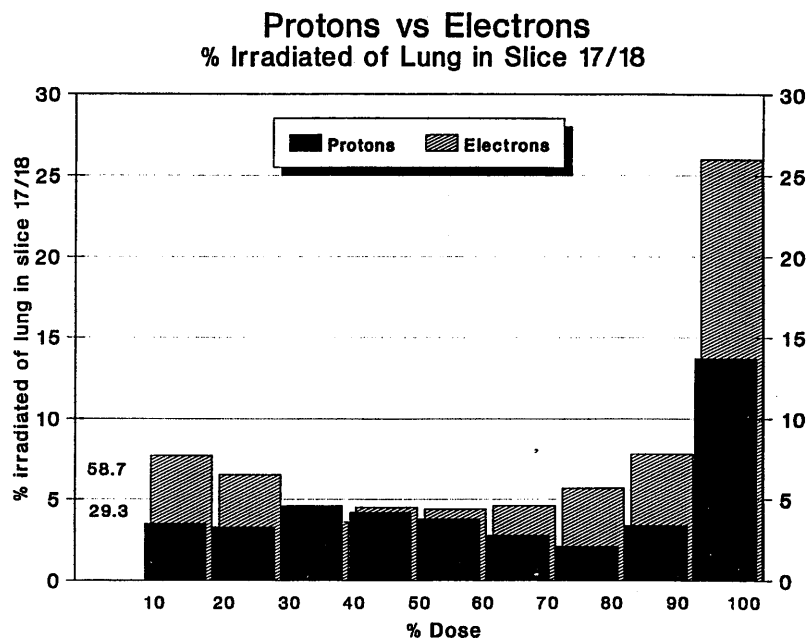


Figure 3. Dose volume histogram for Rando phantom slice 17/18.

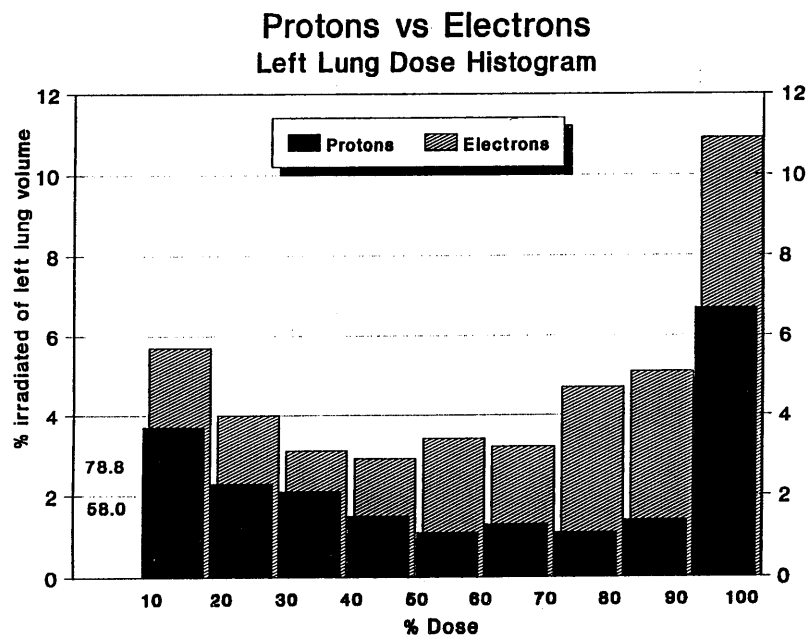


Figure 4. Dose volume histogram for entire lung of Random phantom.